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FORM PTO-1390 (REV. 11-2000) U.S DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER

3286-0154P

U.S. APPLICATION NO. (If known, see 37 CFR 1.5)

09/787778

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/DE99/03088	September 22, 1999	September 22, 1998

TITLE OF INVENTION

METHOD FOR REPRODUCING DIRECT CURRENTS, AND A DIRECT CURRENT TRANSFORMER FOR CARRYING OUT *

APPLICANT(S) FOR DO/EO/US

BAUMGAERTEL, Ulrich; ROEHL, Wolfgang; FRANKE, Henry; HOCHGRAEF, Holger

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39 (1).
4. ☒ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. ☒ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☒ has been transmitted by the International Bureau. WO 00/17663
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
   a. ☒ is transmitted herewith.
   b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4)
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)).
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ An English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 20. below concern document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98-International Search Report (PCT/ISA/210) w/ 13 documents
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A FIRST preliminary amendment.
14. ☐ A SECOND or SUBSEQUENT preliminary amendment.
15. ☒ A substitute specification.
16. ☐ A change of power of attorney and/or address letter.
17. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821-1.825.
18. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
19. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
20. ☒ Other items or information:
    1.) Two (2) Sheets of Formal Drawings

*THE METHOD

JC03 Rec'd PCT/PTO 22 MAR 2001

U.S. APPLICATION NO (if known, see 37 CFR 1.5)	INTERNATIONAL APPLICATION NO	ATTORNEY'S DOCKET NUMBER
09/787778	PCT/DE99/03088	3286-0154P

21. ☒ The following fees are submitted:

	CALCULATIONS	PTO USE ONLY
BASIC NATIONAL FEE (37 CFR 1.492(a)(1)-(5): Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO. . . . . **$1,000.00** International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO . . . . **$860.00** International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO. . . . . **$710.00** International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) . . . . **$690.00** International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4). . . . . **$100.00** **ENTER APPROPRIATE BASIC FEE AMOUNT =**	$ 860.00	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☒ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).	$ 130.00	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total Claims	12 - 20 =	0	X $18.00	$ 0	
Independent Claims	2 - 3 =	0	X $80.00	$ 0	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)		None	+ $270.00	$ 0	
TOTAL OF ABOVE CALCULATIONS =				$ 990.00	
☐ Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2.				$ 0	
SUBTOTAL =				$ 990.00	
Processing fee of **$130.00** for furnishing the English translation later than ☐20 ☐30 months from the earliest claimed priority date (37 CFR 1.492(f)). +				$ 0	
TOTAL NATIONAL FEE =				$ 990.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). **$40.00** per property +				$ 0	
TOTAL FEES ENCLOSED =				$ 990.00	
				Amount to be: refunded	$
				charged	$

a. ☒ A check in the amount of $ 990.00 to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account. No. ________ in the amount of $______ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 02-2448.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

Send all correspondence to:
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Date: March 22, 2001

By [signature]
Donald J. Daley, #34,313

/cqc

PATENT
3286-0154P

IN THE U.S. PATENT AND TRADEMARK OFFICE

Applicants: Ulrich BAUMGAERTEL et al.

Application No.: **NEW**

Filed: March 22, 2001

For: METHOD FOR REPRODUCING DIRECT CURRENTS, AND A DIRECT CURRENT TRANSFORMER FOR CARRYING OUT THE METHOD

PRELIMINARY AMENDMENT

Assistant Commissioner for Patents
Washington, DC 20231

March 22, 2001

Sir:

The following preliminary amendments and remarks are respectfully submitted in connection with the above-identified application.

IN THE ABSTRACT

Please replace the Abstract with the attached revised Abstract.

IN THE CLAIMS

Please replace the original claims with the following new claims:

1. A method for reproducing direct currents with the aid of a primary winding through which a direct current to be measured flows and which is magnetically coupled to a secondary winding via an iron core, comprising:

integrating a current signal supplied from the secondary winding;

supplying the integrated current value to at least one of a measurement device and a trigger circuit of a switching device; and

adjusting the supplied integrated current value at predetermined time intervals by a primary current to be measured, the adjustment being determined with the assistance of a magnetic field sensor for measuring the magnetic field in the iron core using a compensation method including,

determining a current for setting a magnetic field in the iron core to zero, in a direction opposite to the primary current, in a compensation winding; and

correcting the integrated current value based upon the determined current.

2. The method as claimed in claim 1, wherein the secondary winding is used as the compensation winding.

3. The method as claimed in claim 1, wherein a linear-rising direct current is fed into the secondary winding in order to carry out the compensation method.

4. A direct current transformer having a primary winding through which direct current to be measured flows and which is magnetically coupled to a secondary winding via an iron core, comprising:

a magnetic field sensor for measuring a magnetic field of the iron core;

an integration circuit, connected to the secondary winding and having an output connected to at least one of a measurement device and a trigger circuit of a switching device, for integrating a current signal supplied from the secondary winding

and for supplying the integrated current value to at least one of the measurement device and trigger circuit;

a compensation circuit, connected to at least one of the secondary winding via a changeover switch and a separate compensation winding wound on the iron core, for compensating the magnetic field; and

a controllable DC source; and

an evaluation circuit for processing a current value of the DC source when the magnetic field has been compensated, in order to adjust the integrated current value of the integration circuit at predetermined time intervals.

5. The direct current transformer as claimed in claim 4, wherein the iron core includes an air gap wherein the magnetic field sensor is arranged in at least one of the air gap and a vicinity of the air gap.

6. The direct current transformer as claimed in claim 4, wherein the magnetic field sensor is a Hall probe.

7. The direct current transformer as claimed in claim 4, wherein the magnetic field sensor is a magnetoresistive sensor.

8. The direct current transformer as claimed in claim 4, wherein the magnetic field sensor is an indicator winding to which a balanced alternating current can be applied and whose voltage imbalance can be evaluated in the evaluation circuit in order to measure the magnetic field in the iron core.

Please add the following new claims:

-- 9. The method of claim 2, wherein a linear-rising direct current is fed into a separate compensation winding in order to carry out the compensation method.

10. The direct current transformer as claimed in claim 5, wherein the magnetic field sensor is a Hall probe.

11. The direct current transformer as claimed in claim 5, wherein the magnetic field sensor is a magnetoresistive sensor.

12. The direct current transformer as claimed in claim 5, wherein the magnetic field sensor is an indicator winding to which a balanced alternating current can be applied and whose voltage imbalance can be evaluated in the evaluation circuit in order to measure the magnetic field in the iron core. --

REMARKS

Claims 1-12 are now present in this application, with new claims 9-12 being added by the present Preliminary Amendment. It should be noted that the amendments to original claims 1-8 of the present application are non-narrowing amendments made solely to place the claims in proper form for U.S. practice and not to overcome any prior art or for any other statutory considerations. For example, amendments have been made to remove reference numerals in the claims; remove the European phrase "characterized in that"; remove multiple dependencies in the claims; and to place claims in a more recognizable form, including using the transitional phrase "comprising" as well as the phrase "wherein". Other such non-narrowing amendments include changing the

phrase "or" to --at least one of--, and reorganizing method (separate clauses beginning with "-ing" verbs) and apparatus (elements set forth in separate paragraphs) claims in a more recognizable U.S. form. Again, all amendments are non-narrowing and have been made solely to place the claims in proper form for U.S. practice and not to overcome any prior art or for any other statutory considerations.

SUBSTITUTE SPECIFICATION

In accordance with 37 C.F.R. §1.125, a substitute specification has been included in lieu of substitute paragraphs in connection with the present Preliminary Amendment. The substitute specification is submitted in clean form, attached hereto, and is accompanied by a marked-up version showing the changes made to the original specification. The changes have been made in an effort to place the specification in better form for U.S. practice. No new matter has been added by these changes to the specification. Further, the substitute specification includes paragraph numbers to facilitate amendment practice as requested by the U.S. Patent and Trademark Office.

CONCLUSION

Accordingly, in view of the above amendments and remarks, an early indication of the allowability of each of claims 1-12 in connection with the present application is earnestly solicited.

Should there be any outstanding matters that need to be resolved in the present application, the Examiner is respectfully requested to contact Donald J. Daley at the telephone number of the undersigned below.

If necessary, the Commissioner is hereby authorized in this, concurrent, and future replies, to charge payment or credit any overpayment to Deposit Account No. 02-2448 for any additional fees required under 37 C.F.R. § 1.16 or under 37 C.F.R. § 1.17; particularly, extension of time fees.

Respectfully submitted,

BIRCH, STEWART, KOLASCH & BIRCH, LLP

By: ______________________________
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SUBSTITUTE SPECIFICATION

METHOD FOR REPRODUCING DIRECT CURRENTS, AND A DIRECT CURRENT TRANSFORMER FOR CARRYING OUT THE METHOD

[0001] This application is the national phase under 35 U.S.C. § 371 of PCT International Application No. PCT/DE99/03088 which has an International filing date of September 22, 1999, which designated the United States of America.

Field of the Invention

[0002] The invention relates to a method for reproducing direct currents, in particular for use in DC switchgear, with the aid of a primary winding through which the direct current to be measured flows and which is magnetically coupled to a secondary winding via an iron core. It further relates to a direct current transformer which is suitable for carrying out the method.

Background of the Invention

[0003] The detection of currents in DC circuits is associated with greater technical problems than such detection of currents in AC circuits, in which transmission to a measurement device or to a tripping circuit of a switching device can be carried out using magnetic transformers.

[0004] Furthermore, there is the requirement for low-voltage switchgear for the measurement to be carried out as far as possible from the system, that is to say without providing external energy from an additional energy source which provides an auxiliary voltage. This is also only a minor problem in AC networks, or at least with an energy source having only a low power level.

[0005] It is known for the primary current to be measured using magnetic devices, that is to say with

the aid of Hall probes or magnetoresistive sensors. However, it has been found that this method is not very suitable, at least for the preferred situation here, since the primary current cannot be reproduced with sufficient accuracy. As such, spurious tripping of the overcurrent release can thus easily occur.

[0006] It is also known for a measurement resistor (shunt) to be inserted in the primary circuit and for the voltage to be supplied via this measurement resistor to an isolating amplifier, whose output side acts on the tripping circuit. However, this solution is technically highly complex owing to the requirements which the isolating amplifier has to satisfy. Furthermore, there is a continuous, high power loss in the measurement resistor.

[0007] EP-A 0 651 258 discloses a measurement method for direct currents, in which the primary conductor is magnetically coupled to a field winding via an iron core. The latter is energized with a regular, triangular-waveform alternating current, which allows pulses to be produced at regular intervals in a further winding, which is used as a measurement coil. If the iron core is now premagnetized in one direction or the other by means of the primary direct current, then the shift in the hysteresis curve of the iron core changes the interval between the measured pulses, and this can be evaluated as a measure of the primary current to be measured. This solution is likewise very complex in terms of circuitry and requires the continuous provision of an auxiliary voltage with a corresponding power level, thus resulting in a not inconsiderable energy requirement.

[0008] A further method for measuring direct currents is based on the use of a field winding to compensate for a magnetic field caused by the direct current in an iron core. The magnetic field in an air gap in the iron core is measured using a magnetic field sensor, in

order to control the compensation current in the field winding. The current flowing in the field winding once compensation has been carried out, that is to say once the total field measured by the magnetic field sensor has become zero, is used as a measure of the primary direct current. The method is known, for example, from EP-A 0 294 590 or from DE-A 38 15 100.

[0009] A further option with the aid of magnetic field compensation is described in UK-A 2 029 973. According to this solution, a current in the form of a ramp is fed continuously and repeatedly into the compensation winding, and the magnetic field in the iron core is measured via an indicator winding.

[0010] The compensation method likewise requires a considerable amount of energy to provide a continuous compensation current, and is thus not suitable for the above-mentioned purpose.

SUMMARY OF THE INVENTION

[0011] The invention is based on the object of specifying a measurement method. In one aspect, it involves a direct current transformer, by means of which direct currents can be reproduced as accurately as possible and using considerably less energy.

[0012] According to the invention, the object is achieved by integration of the current signal which is supplied from the secondary winding of an iron core where the current to be measured flows through a primary winding, and by the integrated current value being supplied to a measurement device or to a trigger circuit of a switching device. The integrated current value is preferably adjusted at predetermined time intervals by determining the primary current to be measured with the assistance of a magnetic field sensor, for measuring the magnetic field in the iron core. This is achieved using a compensation method in which the magnetic field in the iron core is set to

zero by means of a current, in the opposite direction to the primary current, in a compensation winding, and by the integrated current value being corrected to this value.

[0013] The method can expediently be carried out such that the secondary winding is used as the compensation winding for the measurement based on the compensation method.

[0014] The compensation method can advantageously be carried out such that a linear-rising direct current is fed into the secondary winding or into a separate compensation winding.

[0015] The method manages with only a fraction of the energy required by previously known DC/DC converters, since the compensation method is carried out only at time intervals in order to compensate for the drift in the current value determined using the integration method.

[0016] According to the invention, a direct current transformer which is suitable for carrying out the method has a primary winding, through which the primary direct current to be measured flows, and a secondary winding. The windings are magnetically coupled via an iron core. The device further includes a magnetic field sensor for measuring the magnetic field of the iron core and an integration circuit which is connected to the secondary winding, and whose output is connected to a measurement device or to a trigger circuit of a switching device. Finally, a compensation circuit is connected to the secondary winding via a changeover switch, or is connected to a separate compensation winding wound on the iron core. This compensation circuit includes a controllable DC source and an evaluation circuit which processes the current value of the DC source when the magnetic field has been compensated, that is to say when the magnetic flux is

equal to zero, in order to adjust the integration circuit.

[0017] The magnetic field sensor may be a Hall probe, a magnetoresistive sensor or an indicator winding into which a balanced alternating current is injected and whose voltage imbalance or balance is a measure of the magnetic field in the iron core.

[0018] The iron core is expediently provided with an air gap, in which or in whose vicinity the magnetic field sensor is arranged.

[0019] The secondary winding supplies a signal which corresponds to the di/dt of the primary direct current. The downstream evaluation circuit, preferably based on a microprocessor, integrates the signal from the secondary winding to form the primary direct current. It can then use this value in a known manner to carry out the overcurrent protection.

[0020] Determination of the primary current necessitates long-term integration, in which minor errors over very long times can lead to major discrepancies between the calculated value and the true primary current, so that an overcurrent release would operate unnecessarily. In order to avoid this undesirable long-term effect, the current is measured at certain time intervals with the aid of the magnetic field sensor. For this purpose, a direct current which starts from zero and ramps up linearly with time is fed into the secondary winding or into a separate compensation winding. At the same time, the output signal from the magnetic field sensor is monitored. When a reversal point or a change in polarity occurs in the signal, depending on the type of magnetic field sensor used, then the magnetic field in the air gap is zero. Further, the compensation current, multiplied by the number of turns on the secondary or compensation winding, is equal to the primary current. This is then used to correct the previously integrated current

value. After this, the current can once again be detected by integration.

[0021] If an indicator winding on the iron core is used for the magnetic field measurement, then a balanced alternating current is injected into this indicator winding. The voltage is measured in parallel with the indicator winding. If the magnetic field is not equal to zero, then the magnetic characteristic of the iron core results in the voltage being imbalanced to a greater or lesser extent. When the magnetic field finally becomes zero as the compensation current rises, then this results in a balanced AC voltage. The sought measurement point has then been reached. In contrast with the compensation method described in relation to the prior art, there is no need to control the compensation current in this case. In fact, the measurement process can be terminated once the linear-rising compensation current has resulted in the magnetic field in the iron core becoming zero.

[0022] The use of such an indicator winding has the advantage over other magnetic field sensors that it is considerably more resistant to temperature. The temperature resistance depends only on the insulation class of the winding. Overtemperatures up to 200°C may be acceptable, with appropriate insulation.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] The invention will be explained in more detail in the following text with reference to an exemplary embodiment. In the associated drawings:

Figure 1 shows an outline illustration of the arrangement required for the direct current transformer,

Figure 2 shows the signal produced during regular trimming with various magnetic field sensors,

Figure 3 shows a block diagram of an arrangement for compensation measurements.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0024] Figure 1 shows an outline illustration of the arrangement which is required to carry out the method. A primary electrical conductor 1 of a DC network is passed through an iron core 2 of the direct current transformer. The iron core 2 is provided with an air gap 3 in which a magnetic field sensor 4 is accommodated. A secondary winding 5 is fitted to the iron core 2, and its current supplies the signal to be evaluated. The current signal is integrated in an integration circuit, which is not shown here, and then supplies a model of the primary direct current I_{Prim}.

[0025] In order to adjust the integrated current value, a second current measurement is carried out with the aid of the magnetic field sensor 4. For this purpose, the current measurement process carried out until that point in time is briefly interrupted and a linear-rising compensation current I_{sec} is fed into the secondary winding 5 until the output signal I_I of the magnetic field sensor 4 reaches a reversal point or a polarization change, as is shown in figure 2. The compensation current I_{sec}, multiplied by the number of turns w, corresponds to the primary direct current I_{Prim} to be measured. The current value, which was previously determined by means of integration, is now corrected using this measured value.

[0026] Figure 3 shows one option for obtaining the field measurement in the iron core 2. The secondary winding 5 is in this case used as a compensation winding. The illustration shows only operation during the compensation phase. The secondary winding 5 is connected to a controllable DC source 6 which, for example, feeds a linear-rising current into the secondary winding 5.

[0027] A balanced alternating current, which is supplied from an AC source 8, is fed into an indicator winding 7. The voltage across the indicator winding 7 is measured. In the positive half-cycle, the positive peak value is stored in a peak-value store 9, and in the negative half-cycle, the negative peak value is stored in a peak-value store 10. Capacitors, for example, are suitable for use as the peak-value stores. The two values are then compared in a comparator 11.

[0028] If the comparator value is not equal to zero, this means that the voltage is unbalanced, owing to the magnetic characteristics of the iron core 2 which has been premagnetized by the primary current I_{Prim}.

[0029] If the comparator value is zero, then the measured AC voltage across the indicator winding 7 is balanced. This is therefore a measure that the magnetic field in the iron core is zero, that is to say the primary direct current I_{Prim} has been compensated. The current I_{sec} in the secondary winding 5 is, at this instant, a measure of the primary direct current I_{Prim}. The value is retained in order to use it subsequently to correct the current value obtained using the integration method. The integration process and the current value correction can be expediently carried out digitally in a microprocessor, for example, which is not shown here. For use in a trigger circuit of a DC switching device, the trigger circuit can in any case, already be equipped with a microprocessor, for example, which can also be used for this purpose.

[0030] The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

ABSTRACT OF THE DISCLOSURE

A current signal, which is supplied from the secondary winding of an iron core on which the current to be measured flows through a primary winding, is integrated. The integrated current value is supplied to a measurement device or to a trigger circuit of a switching device. The integrated current value is adjusted at predetermined time intervals by determining the primary current to be measured, using a magnetic field sensor. The primary current is determined by a compensation method using the magnetic field sensor to measure the magnetic field in the iron core, and the integrated current value is corrected based upon the determined value.

21PRTS

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PCT/DE99/03088
GR 1998 P 04184 WO

Description

Method for reproducing direct currents, and a DC/DC converter for carrying out the method

The invention relates to a method for reproducing direct currents, in particular for use in DC switchgear, with the aid of a primary winding through which the direct current to be measured flows and which is magnetically coupled to a secondary winding via an iron core, and to a DC/DC converter which is suitable for carrying out the method.

The detection of currents in DC circuits is associated with greater technical problems than such detection of currents in AC circuits, in which transmission to a measurement device or to a tripping circuit of a switching device can be carried out using magnetic transformers.

Furthermore, there is the requirement for low-voltage switchgear for the measurement to be carried out as far as possible from the system, that is to say without providing external energy from an additional energy source which provides an auxiliary voltage, which is likewise only a minor problem in AC networks, or at least with an energy source having only a low power level.

It is known for the primary current to be measured using magnetic means, that is to say with the aid of Hall probes or magnetoresistive sensors. However, it has been found that this method is not very suitable, at least for the preferred situation here, since the primary current cannot be reproduced with sufficient accuracy, and spurious tripping of the overcurrent release can thus easily occur.

It is also known for a measurement resistor (shunt) to be inserted in the primary circuit and for the voltage to be supplied via this measurement resistor to an isolating amplifier, whose output side acts on the tripping circuit. However, this solution is technically highly complex owing to the requirements which the isolating amplifier has to satisfy. Furthermore, there is a continuous, high power loss in the measurement resistor.

EP-A 0 651 258 discloses a measurement method for direct currents, in which the primary conductor is magnetically coupled to a field winding via an iron core. The latter is energized with a regular, triangular-waveform alternating current, which allows pulses to be produced at regular intervals in a further winding, which is used as a measurement coil. If the iron core is now premagnetized in one direction or the other by means of the primary direct current, then the shift in the hysteresis curve of the iron core changes the interval between the measured pulses, and this can be evaluated as a measure of the primary current to be measured. This solution is likewise very complex in terms of circuitry and requires the continuous provision of an auxiliary voltage with a corresponding power level, thus resulting in a not inconsiderable energy requirement.

A further method for measuring direct currents is based on the use of a field winding to compensate for a magnetic field caused by the direct current in an iron core. The magnetic field in an air gap in the iron core is measured using a magnetic field sensor, in order to control the compensation current in the field winding. The current flowing in the field winding once compensation has been carried out, that is to say once the total field measured by the magnetic field sensor has become zero, is used as a measure of the primary

direct current. The method is known, for example, from EP-A 0 294 590 or from DE-A 38 15 100.

A further option with the aid of magnetic field compensation is described in UK-A 2 029 973. According to this solution, a current in the form of a ramp is fed continuously and repeatedly into the compensation winding, and the magnetic field in the iron core is measured via an indicator winding.

The compensation method likewise requires a considerable amount of energy to provide a continuous compensation current, and is thus not suitable for the abovementioned purpose.

The invention is based on the object of specifying a measurement method and, finally, a DC/DC converter, by means of which direct currents can be reproduced as accurately as possible and using considerably less energy.

According to the invention, the object is achieved by integration of the current signal which is supplied from the secondary winding of an iron core where the current to be measured flows through a primary winding, and by the integrated current value being supplied to a measurement device or to a tripping circuit of a switching device, with the integrated current value being trimmed at predetermined time intervals by determining the primary current to be measured with the assistance of a magnetic field sensor for measuring the magnetic field in the iron core, using the compensation method in which the magnetic field in the iron core is set to zero by means of a current, in the opposite direction to the primary current, in a compensation winding, and by the integrated current value being corrected to this value.

The method can expediently be carried out such that the secondary winding is used as the compensation winding for the measurement based on the compensation method.

The compensation method can advantageously be carried out such that a linear-rising direct current is fed into the secondary winding or into a separate compensation winding.

The method manages with only a fraction of the energy required by previously known DC/DC converters, since the compensation method is carried out only at time intervals in order to compensate for the drift in the current value determined using the integration method.

According to the invention, a DC/DC converter which is suitable for carrying out the method has a primary winding, through which the primary direct current to be measured flows, and a secondary winding, which windings are magnetically coupled via an iron core, and has a magnetic field sensor for measuring the magnetic field of the iron core, an integration circuit which is connected to the secondary winding and whose output is connected to a measurement device or to a tripping circuit of a switching device, and a compensation circuit which is connected to the secondary winding via a changeover switch, or is connected to a separate compensation winding wound on the iron core. This compensation circuit comprises a controllable DC source and an evaluation circuit which processes the current value of the DC source when the magnetic field has been compensated, that is to say when the magnetic flux is equal to zero, in order to trim the integration circuit.

The magnetic field sensor may be a Hall probe, a magnetoresistive sensor or an indicator winding into which a balanced alternating current is injected and whose voltage imbalance or balance is a measure of the magnetic field in the iron core.

The iron core is expediently provided with an air gap, in which or in whose vicinity the magnetic field sensor is arranged.

The secondary winding supplies a signal which corresponds to the di/dt of the primary direct current. The downstream evaluation circuit, preferably based on a microprocessor, integrates the signal from the secondary winding to form the primary direct current, and can use this value in a known manner to carry out the overcurrent protection.

Determination of the primary current necessitates long-term integration, in which minor errors over very long times can lead to major discrepancies between the calculated value and the true primary current, so that an overcurrent release would operate unnecessarily. In order to avoid this undesirable long-term effect, the current is measured at certain time intervals with the aid of the magnetic field sensor. For this purpose, a direct current which starts from zero and ramps up linearly with time is fed into the secondary winding or into a separate compensation winding. At the same time, the output signal from the magnetic field sensor is monitored. When a reversal point or a change in polarity occurs in the signal, depending on the type of magnetic field sensor used, then the magnetic field in the air gap is zero, and the compensation current, multiplied by the number of turns on the secondary or compensation winding, is equal to the primary current, which is then used to correct the previously integrated current value. After this, the current can once again be detected by integration.

If an indicator winding on the iron core is used for the magnetic field measurement, then a balanced alternating current is injected into this indicator winding. The voltage is measured in parallel with the indicator winding. If the magnetic field is

not equal to zero, then the magnetic characteristic of the iron core results in the voltage being imbalanced to a greater or lesser extent. When the magnetic field finally becomes zero as the compensation current rises, then this results in a balanced AC voltage. The sought measurement point has then been reached. In contrast with the compensation method described in relation to the prior art, there is no need to control the compensation current in this case. In fact, the measurement process can be terminated once the linear-rising compensation current has resulted in the magnetic field in the iron core becoming zero.

The use of such an indicator winding has the advantage over other magnetic field sensors that it is considerably more resistant to temperature. The temperature resistance depends only on the insulation class of the winding. Overtemperatures up to 200°C may be acceptable, with appropriate insulation.

The invention will be explained in more detail in the following text with reference to an exemplary embodiment. In the associated drawings:

Figure 1 shows an outline illustration of the arrangement required for the DC/DC converter,

Figure 2 shows the signal produced during regular trimming with various magnetic field sensors,

Figure 3 shows a block diagram of an arrangement for compensation measurements.

Figure 1 shows an outline illustration of the arrangement which is required to carry out the method. A primary electrical conductor 1 of a DC network is passed through an iron core 2 of the DC/DC converter. The iron

core 2 is provided with an air gap 3 in which a magnetic field sensor 4 is accommodated. A secondary winding 5 is fitted to the iron core 2, and its current supplies the signal to be evaluated. The current signal is integrated in an integration circuit, which is not shown here, and then supplies a model of the primary direct current I_{Prim}.

In order to trim the integrated current value, a second current measurement is carried out with the aid of the magnetic field sensor 4. For this purpose, the current measurement process carried out until that point in time is briefly interrupted and a linear-rising compensation current I_{sec} is fed into the secondary winding 5 until the output signal I_I of the magnetic field sensor 4 reaches a reversal point or a polarization change, as is shown in figure 2. The compensation current I_{sec} multiplied by the number of turns w corresponds to the primary direct current I_{Prim} to be measured. The current value, which was previously determined by means of integration, is now corrected using this measured value.

Figure 3 shows one option for obtaining the field measurement in the iron core 2. The secondary winding 5 is in this case used as a compensation winding. The illustration shows only operation during the compensation phase. The secondary winding 5 is connected to a controllable DC source 6 which, for example, feeds a linear-rising current into the secondary winding 5.

A balanced alternating current, which is supplied from an AC source 8, is fed into an indicator winding 7. The voltage across the indicator winding 7 is measured. In the positive half-cycle, the positive peak value is stored in a peak-value store 9, and in the negative half-cycle, the negative peak value is stored in a peak-value store 10. Capacitors, for example, are

suitable for use as the peak-value stores. The two values are then compared in a comparator 11.

If the comparator value is not equal to zero, this means that the voltage is unbalanced, owing to the magnetic characteristics of the iron core 2 which has been premagnetized by the primary current I_{Prim}.

If the comparator value is zero, then the measured AC voltage across the indicator winding 7 is balanced, and is thus a measure that the magnetic field in the iron core is zero, that is to say the primary direct current I_{Prim} has been compensated. The current I_{sec} in the secondary winding 5 is, at this instant, a measure of the primary direct current I_{Prim}. The value is retained in order to use it subsequently to correct the current value obtained using the integration method. The integration process and the current value correction are expediently carried out digitally in a microprocessor, which is not shown here. For use in a tripping circuit of a DC switching device, the tripping circuit is in any case already equipped with a microprocessor, which can also be used for this purpose.

Patent Claims

1. A method for reproducing direct currents, in particular for use in overcurrent releases in DC switchgear, with the aid of a primary winding (1) through which the direct current to be measured flows and which is magnetically coupled to a secondary winding (5) via an iron core (2),
characterized
in that the current signal supplied from the secondary winding (5) is integrated, and the integrated current value is supplied to a measurement device or to a tripping circuit of a switching device, with trimming of the integrated current value being carried out at predetermined time intervals by the primary current to be measured being determined with the assistance of a magnetic field sensor (4) for measuring the magnetic field in the iron core (2), using the compensation method in which the magnetic field in the iron core (2) is set to zero by means of a current, in the opposite direction to the primary current, in a compensation winding, and by the integrated current value being corrected to this value.

2. The method as claimed in claim 1,
characterized
in that the secondary winding (5) is used as the compensation winding in order to carry out the compensation method.

3. The method as claimed in claim 1 or 2,
characterized
in that a linear-rising direct current is fed into the secondary winding (5) or into a separate compensation winding in order to carry out the compensation method.

4. A DC/DC converter having a primary winding (1) through which the direct current to be measured flows and which is

magnetically coupled to a secondary winding (5) via an iron core (2), for carrying out the method as claimed in one of the preceding claims,
characterized by
a magnetic field sensor (4) for measuring the magnetic field of the iron core (2), an integration circuit which is connected to the secondary winding (5) and whose output is connected to a measurement device or to a tripping circuit of a switching device, and a compensation circuit which is connected to the secondary winding (5) via a changeover switch or is connected to a separate compensation winding wound on the iron core (2), comprising a controllable DC source (6) and an evaluation circuit (9, 10, 11) which processes the current value of the DC source (6) when the magnetic field has been compensated, in order to trim the integration circuit.

5. The DC/DC converter as claimed in claim 4,
characterized
in that the iron core (2) has an air gap (3) in which or in whose vicinity the magnetic field sensor (4) is arranged.

6. The DC/DC converter as claimed in claim 4 or 5,
characterized
in that the magnetic field sensor (4) is a Hall probe.

7. The DC/DC converter as claimed in claim 4 or 5,
characterized
in that the magnetic field sensor (4) is a magnetoresistive sensor.

8. The DC/DC converter as claimed in claim 4 or 5,
characterized
in that the magnetic field sensor (4) is an indicator winding (7) to which a balanced alternating current can be applied and whose voltage imbalance can be evaluated in the evaluation circuit (9, 10, 11) in order to measure the magnetic field in the iron core (2).

1998P04184WO

Abstract

Method for reproducing direct currents, and a DC/DC converter for carrying out the method

The invention describes a method for reproducing direct currents, in particular for use in DC switchgear, and a DC/DC converter for carrying out the method.

There is a requirement for low-voltage switchgear for the primary direct current to be measured as far as possible from the system, that is to say without providing external energy from an additional energy source which provides an auxiliary voltage, or at least with an energy source having only a low power level.

With the present invention, the current signal which is supplied from the secondary winding of an iron core on which the current to be measured flows through a primary winding is integrated, and the integrated current value is supplied to a measurement device or to a tripping circuit of a switching device, with the integrated current value being trimmed at predetermined time intervals by determining the primary current to be measured with the assistance of a magnetic field sensor for measuring the magnetic field in the iron core, using the compensation method, and by the integrated current value being corrected to this value.

The method manages with only a fraction of the energy required by previously known DC/DC converters, since the compensation method is carried out only at time intervals in order to compensate for the drift in the current value determined using the integration method.

Figure 1

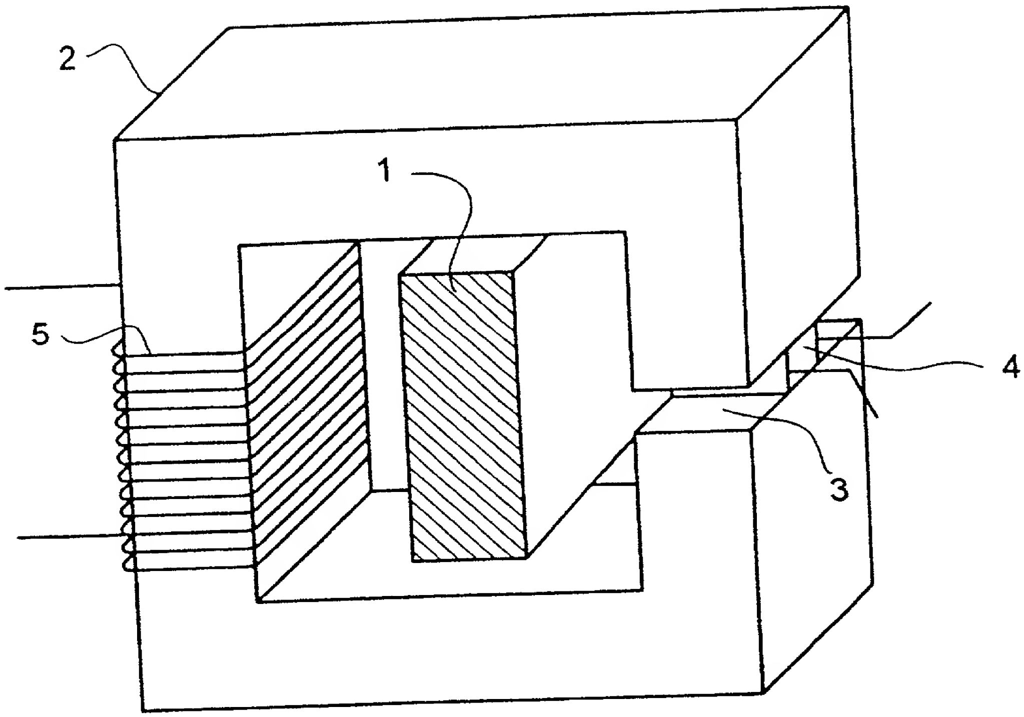

FIG 1

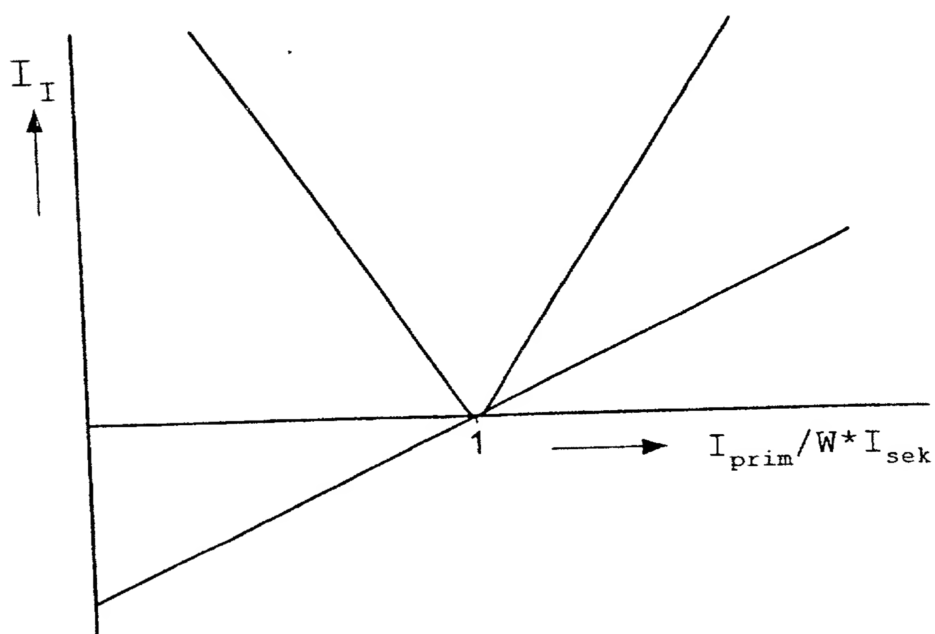

FIG 2

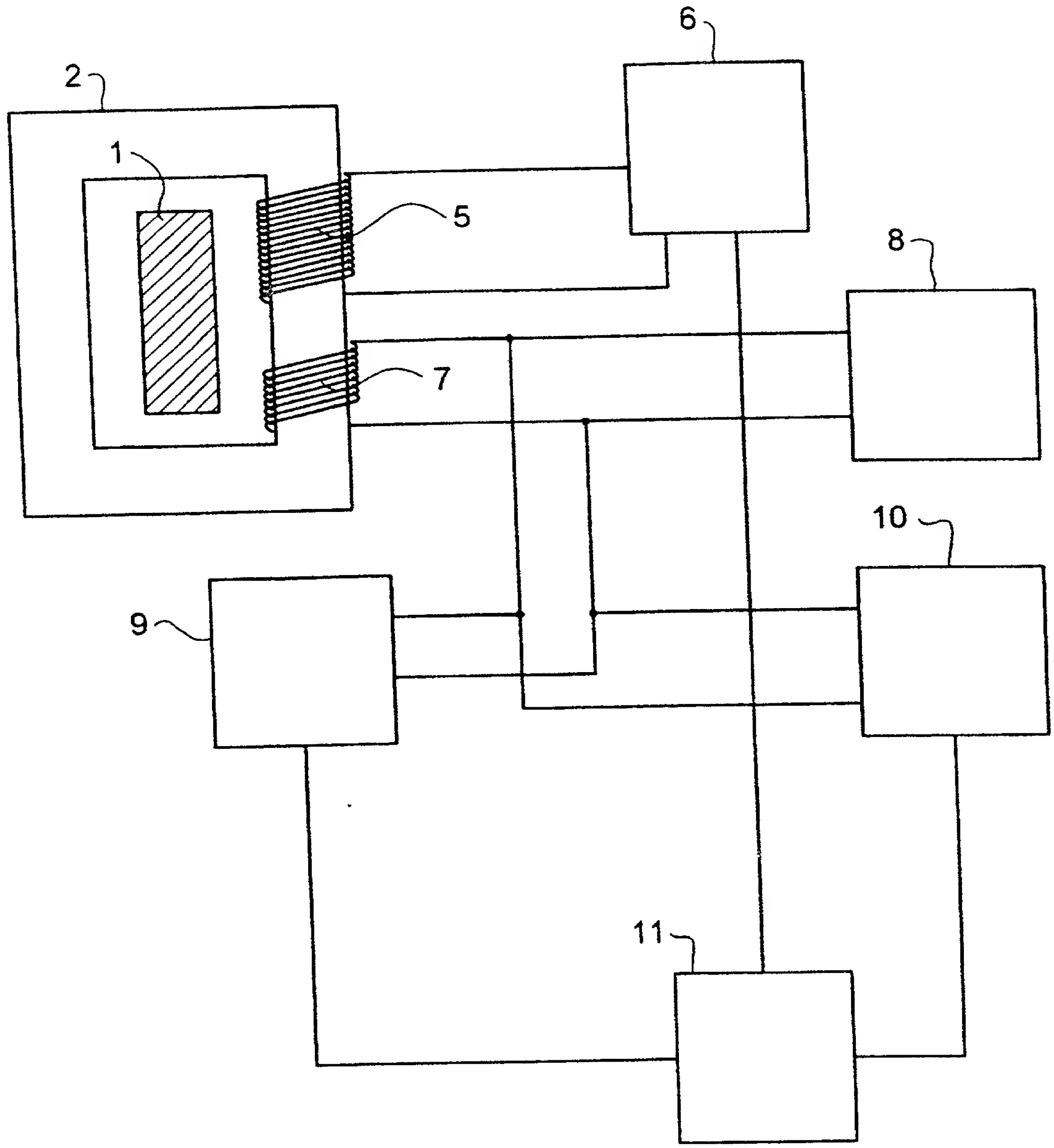

FIG 3

Declaration and Power of Attorney For Patent Application
Erklärung Für Patentanmeldungen Mit Vollmacht
German Language Declaration

Als nachstehend benannter Erfinder erkläre ich hiermit an Eides Statt:

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Verfahren zur Abbildung von Gleichstroemen und Gleichstromwandler zur Durchfuehrung des Verfahrens

deren Beschreibung

(zutreffendes ankreuzen)
☐ hier beigefügt ist.
☒ am 22.09.1999 als
PCT internationale Anmeldung
PCT Anmeldungsnummer PCT/DE99/03088
eingereicht wurde und am ________
abgeändert wurde (falls tatsächlich abgeändert).

Ich bestätige hiermit, dass ich den Inhalt der obigen Patentanmeldung einschliesslich der Ansprüche durchgesehen und verstanden habe, die eventuell durch einen Zusatzantrag wie oben erwähnt abgeändert wurde.

Ich erkenne meine Pflicht zur Offenbarung irgendwelcher Informationen, die für die Prüfung der vorliegenden Anmeldung in Einklang mit Absatz 37, Bundesgesetzbuch, Paragraph 1.56(a) von Wichtigkeit sind, an.

Ich beanspruche hiermit ausländische Prioritätsvorteile gemäss Abschnitt 35 der Zivilprozessordnung der Vereinigten Staaten, Paragraph 119 aller unten angegebenen Auslandsanmeldungen für ein Patent oder eine Erfindersurkunde, und habe auch alle Auslandsanmeldungen für ein Patent oder eine Erfindersurkunde nachstehend gekennzeichnet, die ein Anmeldedatum haben, das vor dem Anmeldedatum der Anmeldung liegt, für die Priorität beansprucht wird.

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

Method for reproducing direct currents, and a direct current transformer for carrying out the method

the specification of which

(check one)
☐ is attached hereto.
☒ was filed on 22.09.1999 as
PCT international application
PCT Application No. PCT/DE99/03088
and was amended on ________
(if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

German Language Declaration

Prior foreign appplications
Priorität beansprucht

Priority Claimed

19845778.2 (Number) (Nummer)	DE (Country) (Land)	22.09.1998 (Day Month Year Filed) (Tag Monat Jahr eingereicht)	☒ Yes Ja	☐ No Nein
(Number) (Nummer)	(Country) (Land)	(Day Month Year Filed) (Tag Monat Jahr eingereicht)	☐ Yes Ja	☐ No Nein
(Number) (Nummer)	(Country) (Land)	(Day Month Year Filed) (Tag Monat Jahr eingereicht)	☐ Yes Ja	☐ No Nein

Ich beanspruche hiermit gemäss Absatz 35 der Zivilprozessordnung der Vereinigten Staaten, Paragraph 120, den Vorzug aller unten aufgeführten Anmeldungen und falls der Gegenstand aus jedem Anspruch dieser Anmeldung nicht in einer früheren amerikanischen Patentanmeldung laut dem ersten Paragraphen des Absatzes 35 der Zivilprozeßordnung der Vereinigten Staaten, Paragraph 122 offenbart ist, erkenne ich gemäss Absatz 37, Bundesgesetzbuch, Paragraph 1.56(a) meine Pflicht zur Offenbarung von Informationen an, die zwischen dem Anmeldedatum der früheren Anmeldung und dem nationalen oder PCT internationalen Anmeldedatum dieser Anmeldung bekannt geworden sind.

I hereby claim the benefit under Title 35. United States Code. §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §122, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occured between the filing date of the prior application and the national or PCT international filing date of this application.

PCT/DE99/03088 (Application Serial No.) (Anmeldeseriennummer)	22.09.1999 (Filing Date D, M, Y) (Anmeldedatum T, M, J)	(Status) (patentiert, anhängig, aufgegeben)	pending (Status) (patented, pending, abandoned)
(Application Serial No.) (Anmeldeseriennummer)	(Filing Date D,M,Y) (Anmeldedatum T, M; J)	(Status) (patentiert, anhängig, aufgegeben)	(Status) (patented, pending, abandoned)

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German Language Declaration

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POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. *(list name and registration number)*

And I hereby appoint

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(Supply similar information and signature for third and subsequent joint inventors).

UB

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3W

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Staatsangehörigkeit	Citizenship
Postanschrift	Post Office Address

Voller Name des sechsten Miterfinders:	Full name of sixth joint inventor:
Unterschrift des Erfinders — Datum	Inventor's signature — Date
Wohnsitz: ,	Residence: ,
Staatsangehörigkeit	Citizenship
Postanschrift	Post Office Address

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